Orbital Debris Penetration Effects in Spacecraft Interiors

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Orbital debris penetration of manned spacecraft is accompanied by a number of atmospheric effects that can pose a serious hazard to spacecraft and crew survival. These atmospheric effects can include overpressure, light flash, and temperature rise as hot particles from the penetration process impinge the atmosphere of a manned spacecraft. The objectives of this research have been: (1) to conduct a series of hypervelocity impact tests at the University of Alabama in Huntsville's Aerophysics Research Center to measure these effects, and (2) to formulate a mathematical model for these results for predicting the onset of dangerous levels of overpressure, light, and temperature for a given spacecraft shield design and interior layout.

In these tests, a light gas gun was used to fire orbital debris particle simulants from 0.375 to 0.625 inch in diameter through target simulants into a large test chamber simulating the interior cabin of a spacecraft at 1 atmosphere. The test chamber was instrumented with pressure transducers, light sensors, and temperature gauges to measure the level of blast hazard associated with differing target and penetrator conditions at various distances from the target site (fig. 94). The mitigating effects of interior equipment ranks and

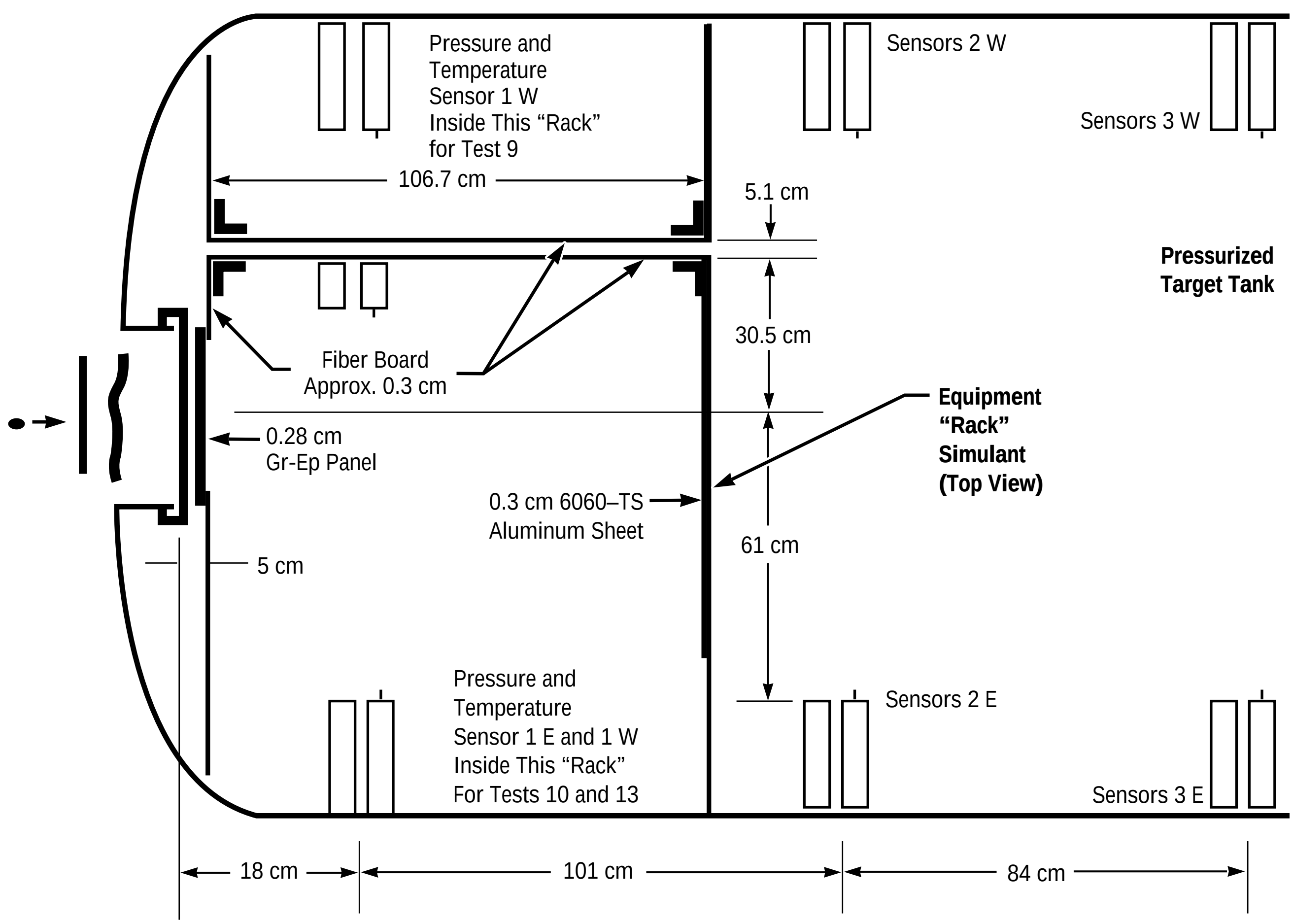

FIGURE 94.—Target chamber arrangement with internal equipment rack simulant.

spall blankets were also measured by placing these elements inside the test chamber against the simulated "pressure wall" of the spacecraft.

Note that overpressure measurements from these tests (table 5) taper off considerably with the distance from the penetrating event (sensors 2 and 3 show lower overpressures than sensor 1) and the presence of internal equipment racks (tests 9, 10, and 13). The peak overpressure measurements occurred at roughly the same time that the internal debris cloud from the penetrated pressure wall passed the overpressure sensors. Temperature test results showed a curious trend toward higher temperatures farther from the point of penetration, although these temperatures occurred much later in time (several hundred milliseconds after impact) than when the debris cloud passed by the sensors (only several milliseconds after impact). These data have led to the theorization that the heated air nearest the point of impact slowly moves through the module, combining with additionally shocked and heated air (downstream) to reach increasingly high overall air temperatures (280+ °C in some cases). Light levels were measured at above 40,000 watts/steradian (27.2 million candles) when directly viewing the target—levels sufficient to cause temporary blindness. However, the level of light as viewed from 90 degrees (i.e., from the side) was less than 20 watts per steradian—well within safe levels.

TABLE 5.—*Overpressure test results.*

Target		1	1	1	2	3	1+ Blanket	1+ Rack	2+ Rack	2+ Rack
Test Number		1	3	6	5	8	11	10		13
Projectile Diameter		1.27 cm 0.500 in	1.59 cm 0.625 in	1.59 cm 0.625 in	1.59 cm 0.625 in	0.95 cm 0.375 in	1.27 cm 0.500 in	1.59 cm 0.625 in	1.59 cm 0.625 in	1.59 cm 0.625 in
Velocity (k/s)		6.70	6.42	6.50	6.58	6.64	6.46	6.63	6.21	6.52
Sensor 1E	Peak Overpressure	117 kPa 17 psi	141 kPa 20.5 psi	110 kPa 16.0 psi	234 kPa 34.0 psi	262 kPa 38.0 psi	38 kPa 5.5 psi	55 kPa 8.0 psi	—	145 kPa 21.0 psi
	Duration of Peak	0.35 msec	0.50 msec	0.45 msec	0.45 msec	0.35 msec	0.20 msec	0.10 msec	—	0.10 msec
Sensor 1W	Peak Overpressure	121 kPa 17.5 psi	148 kPa 21.5 psi	214 kPa 31.0 psi	276 kPa 40.0 psi	193 kPa 28.0 psi	—	97 kPa 14.0 psi	3 kPa* 0.4 psi	207 kPa 30.0 psi
	Duration of Peak	0.35 msec	0.50 msec	0.40 msec	0.40 msec	0.40 msec	—	0.10 msec	0.10* msec	0.10 msec
Sensor 2E	Peak Overpressure	31 kPa 4.5 psi	117 kPa 17.0 psi	103 kPa 15.0 psi	69 kPa 10.0 psi	48 kPa 7.0 psi	—	9 kPa 1.3 psi	5 kPa 0.7 psi	10 kPa 1.4 psi
Sensor 2W	Peak Overpressure	41 kPa 6.0 psi	145 kPa 21.0 psi	97 kPa 14.0 psi	103 kPa 15.0 psi	45 kPa 6.5 psi	24 kPa 18.0 psi	9 kpa 1.3 kPa	3 kPa 0.5 psi	6 kPa 0.9 psi
Sensor 3E	Peak Overpressure	21 kPa 3.0 psi	55 kPa 8.0 psi	83 kPa 12.0 psi	21 kPa 3.0 psi	7 kPa 1.0 psi	34 kPa 5.0 psi	9 kPa 1.3 psi	10 kPa 1.5 psi	8 kPa 1.2 psi
Sensor 3W	Peak Overpressure	17 kPa 2.5 psi	55 kPa 8.0 psi	48 kPa 7.0 psi	28 kPa 4.0 psi	7 kPa 1.0 psi	21 kPa 3.0 psi	9 kPa 1.3 psi	3 kPa 0.5 psi	4 kPa 0.6 psi

*Pressure sensor located in adjacent equipment rack.

Tests with Internal Equipment Present

Given these data, an analytical model predicting the level of overpressure and temperature experienced within the spacecraft cabin as a function of impinging particle characteristics (mass, velocity), shield design, and distance from the penetrating event was generated. This model is being used in conjunction with previously existing military models to quantify and reduce the likelihood of crew injury given these hazardous levels of overpressure, light, and temperature effects in the *International Space Station*. By quantifying the likelihood of loss, specific procedures for measurably increasing crew safety from the unlikely event of orbital debris penetration are being developed.

This series of internal effects research was successful in meeting its primary and secondary objectives: (1) to establish, through experimentation, the level of spacecraft cabin overpressure, light, and temperature that accompanies penetration of typical orbital debris shielding as a function of penetration parameters, shield type, interior equipment, and distance from the source of penetration; and (2) to formulate a mathematical model of these results for predicting the onset of dangerous levels of overpressure, light, and temperature for a given spacecraft shield design and interior layout. A comprehensive NASA/University of Alabama in Huntsville report on these findings will be released at the close of the contract in December 1995.

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